

Francis Bacon

and the Transformation of Early-Modern Philosophy

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The nature of Bacon's project

From arcane learning to public knowledge

Bacon's project was to harness firmly to the yoke of the state a new attitude to knowledge, and in the course of attempting to do this, he was led to think through and transform this new attitude to knowledge. At the most elementary level, his aim was to reform natural philosophy, but what exactly he was reforming, and how he envisaged its reform, are not straightforward questions. The object of this reform was both the practice and the practitioners of natural philosophy. He was concerned to reform a tradition of natural philosophy in which the central ingredients were areas such as natural history and alchemy: empirical, labour-intensive disciplines.

In a pioneering essay, Kuhn attempted to distinguish between what he referred to as the mathematical and the experimental or 'Baconian' traditions.¹ This is a useful first approximation, and it indicates a divergence of research in the seventeenth and eighteenth centuries (although Newton, for example, was considered to have produced models in both traditions, in his *Principia* and his *Opticks*, respectively).² It is only to be expected that this characterisation is of less help in understanding the way in which fields of research were structured at the time Bacon was writing – and of course it is this that we need to understand if we are to comprehend what Bacon's reforms were directed towards – but there is a similar divergence between two broad kinds of discipline. The first is what I shall call 'practical mathematics' (principally geometrical optics, astronomy, statics, hydrostatics, harmonics, as well as some very ele-

1 Thomas S. Kuhn, 'Mathematical versus Experimental Traditions in the Development of Physical Science', in his *The Essential Tension*, 2d ed. (Chicago, 1977), 31–65. Compare Ian Hacking, *The Emergence of Probability* (Cambridge, 1975), who contrasts the 'high' (i.e., mathematical) sciences with the 'low' (i.e., probabilistic) sciences such as medicine and alchemy, which reason probabilistically rather than conclusively.

2 See I. Bernard Cohen, *Franklin and Newton* (Philadelphia, 1956).

mentary kinematics), which had been pursued in irregular bursts of activity – in the Hellenistic Greek diaspora, in mediæval Islam, in twelfth- and thirteenth-century Paris and Oxford – until, starting in Italy and the Netherlands from the mid-sixteenth century onwards, it began to be pursued in a concerted way in Western Europe. Bacon had very little interest in this kind of area. His concerns in natural philosophy were focused on disciplines and activities which make up a second, far more disparate, grouping, the ingredients of which were resolutely practical and relatively piecemeal. Many of them had traditionally been associated with crafts, like metallurgy, where the secrets were jealously protected; or with agriculture where, along with widely shared abilities which those who worked the land picked up as a matter of course, there were closely guarded skills – in viniculture, for example – which were not shared outside the trade; or with the herbal treatment of various maladies, where esoteric knowledge played a very significant role; or with alchemy, where the arcane nature of the knowledge was virtually a *sine qua non* of the discipline.³ William Eamon has recently drawn attention to the shift from esoteric to public knowledge, a shift he traces primarily to the sixteenth and seventeenth centuries, and has shown how it played an important role in the transformation of scientific culture in this period.⁴ There can be little doubt that this is a crucial element in Bacon's reform. As he puts it in the *Advancement of Learning*,

The sciences themselves which have had better intelligence and confederacy with the imagination of man than with his reason, are three in number; Astrology, Natural Magic, and Alchemy; of which sciences nevertheless the ends are noble. For astrology pretendeth to discover that correspondence or concatenation which is between the superior globe and the inferior; natural magic pretendeth to call and reduce natural philosophy from variety of speculations to the magnitude of works; and alchemy pretendeth to make separation of all the unlike parts of bodies which in mixtures of nature are incorporate. But the derivations and prosecutions to these ends, both in the theories and in the practices, are full of error and vanity; which the great professors themselves have sought to veil over and conceal by enigmatical writings, and referring themselves to auricular traditions, and such other devices to save the credit of impostures. (*Adv. Learn. I: Works* iii.289)⁵

3 A good example of the esoteric nature of alchemy is to be found in George Starkey – aka Eirenæus Philalethes ('a peaceful lover of truth') – one of the most important seventeenth-century alchemists: See the discussion of Starkey and this question in William R. Newman, *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge, Mass., 1994), chap. 4.

4 William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton, 1994).

5 As the alchemical adept Abraham Andrewes put it at the beginning of 'The Hunting of the Greene Lyon': 'All haile to the noble Companie / Of true Students in

Yet deep questions are raised by this issue of the transformation of previously esoteric disciplines into public knowledge. There is some case to be made that the esoteric nature of knowledge in the Middle Ages played a crucial positive role in its development. Comparing the situation in the mediæval West with roughly contemporary societies having strong scientific cultures – the Islamic Middle East and China – Toby Huff, pursuing what might broadly be termed a Weberian approach to these questions, has argued that the formation of autonomous corporate bodies, in the wake of the Investiture Controversy (1050–1122), created a decentralisation of responsibilities and expertise which fostered a protected climate, a neutral space for inquiry, in which intellectual innovation could flourish.⁶ What happened as a result of the Investiture Controversy was that the church was effectively formed as a corporation, declaring itself legally autonomous from the secular order and claiming for itself all spiritual authority. Other corporate bodies were soon formed on this model – towns, cities, guilds, universities, professional groups – and the introduction of corporate structure in the last two cases, in particular, meant that the context in which natural philosophy was pursued was very different from that in the Islamic world and China. Mediæval Islamic thought was very much a development of classical and Hellenistic work in the area of ‘practical mathematics’, but individual successes in optics and astronomy could not be followed up properly because of the very localised and isolated level on which this research was pursued. In China, on the other hand, a totalising bureaucratic structure ruled out opportunities for innovation which were not part of some state-sanctioned programme. Moreover, the model for corporate structure brought with it an elaborate legal structure which harmonised legal traditions and provided a foundation for law, in addition producing a new science of law which became a model of intellectual achievement. Crucial to this cultural dominance of law was a staunchly adversarial mode of reasoning, absent in Chinese legal argument and in its relatively internally undifferentiated pursuit of natural knowledge.⁷

Note 5 (*cont.*)

holy *Alchimie*, / Whose noble practice doth hem teach / to vaile their secrets wyth mistie speach’. The poem is given, along with many like it, in Elias Ashmole, *Theatrum Chemicum Britannicum. Containing Severall Poeticall Pieces of our Famous English Philosophers, who have written the Hermetique Mysteries in their owne Ancient Language* (London, 1652), 278.

6 Toby Huff, *The Rise of Early Modern Science: Islam, China, and the West* (Cambridge, 1993).

7 For a critical and far more nuanced evaluation of the contrast between the Greek adversarial or agonistic approach and the Chinese irenic or ‘authority-bound’ approach, see G. E. R. Lloyd, *Adversaries and Authorities: Investigations into Ancient Greek and Chinese Science* (Cambridge, 1996), chap. 2.

So, in sum, what we have is a culture of self-governing autonomous corporate bodies which strictly regulated entry to their ranks and protected the privileges associated with membership. Exclusivity is crucial to such bodies, and Bacon is criticising the exclusivity both of the guilds, where practical information is esoteric by virtue of keeping knowledge or techniques within a trade or profession to which access is then restricted, and of the universities, where an esoteric and often convoluted language renders information inaccessible to all but those accepted into the university system. In the case of the universities, Bacon, in common with some of his reform-minded contemporaries, associates its convoluted systems with its adversarial approach, whose aim is to win arguments rather than produce new knowledge, and he rejects both.

Having suggested, however, that Bacon's project for the reform of natural philosophy is at least in part motivated by a desire to shift from esoteric to public knowledge, a word of qualification is necessary. Bacon did not envisage such reforms, if successful, resulting in universal access to knowledge. Quite the contrary, he explicitly argues against such universal access; rather, he sees such knowledge as being something which might serve the monarch, in some ways on a par with territorial conquest:

And this proficience in navigation and discoveries may plant also an expectation of the further proficience and augmentation of all sciences; because it may seem they are ordained by God to be coevals, that is, to meet in one age. For so the prophet Daniel speaking of the latter times foretelleth ['many pass to and fro, and knowledge shall be multiplied'], as if the openness and through passage of the world and the increase of knowledge were appointed to be in the same ages. (*Adv. Learn. II: Works iii.340*)⁸

The association of the conquest of land with the conquest of knowledge is something strikingly depicted in the frontispiece to his *Instauratio Magna* of 1620, where a warship is shown sailing back through the Pillars of Hercules, a traditional symbol of the limits of knowledge but also an emblem the Spanish kings had commandeered to represent their empire.⁹ Bacon explicitly wants to limit access to such knowledge to the

8 The image is also to be found earlier in *Val. Term.* (*Works iii.220–1*), and later in *De Aug.* (*Works i.514/iv.311–12*) and *Nov. Org. I, Aph. 93* (*Works i.200/iv.92*). On the widespread millenarian reading of the passage from Daniel in the first half of the seventeenth century, see Charles Webster, *The Great Instauration: Science, Medicine and Reform (1626–1660)* (London, 1975), chap. 1.

9 The analogy between territorial conquest and scientific conquest in the science of this period is explored in Timothy Reiss, *The Discourse of Modernism* (Ithaca, 1982), and more recently in Amir Alexander, 'The Imperialist Space of Elizabethan Mathematics', *Studies in History and Philosophy of Science* 26 (1995): 559–92.

monarch: It is to serve national purposes rather than those of some local grouping. In order to do this, however, the information must be acquired and presented in a new way, and correspondingly he wants those who pursue natural philosophy to be very different from traditional practitioners.

A via media

A crucial ingredient in the reform of natural philosophy for Bacon is a reform of its practitioners: If we neglect this element in his programme, we will fail to see what was its practical cutting edge.¹⁰ In this respect, his concerns can be seen as part of a general concern with the reform of behaviour which began outside scientific culture but which was rapidly internalised in English natural philosophy in the seventeenth century.¹¹ A particular way of pursuing natural philosophy was associated with what can only be called a particular form of civility. The investigation of natural processes – observation and experimentation – was contrasted with and pitted against verbal dispute, the first being construed as a procedure by which we actually learn something, the second as consisting of mere unproductive argumentation for its own sake. In a famous passage in the *Advancement of Learning*, Bacon chastises Aristotle on these grounds in strong terms:

And herein I cannot a little marvel at the philosopher Aristotle, that did proceed in such a spirit of difference and contradiction toward all antiquity; undertaking not only to frame new words of science at pleasure, but to confound and extinguish all ancient wisdom; inasmuch as he never nameth or mentioneth an ancient author or opinion, but to confute and reprove. (*Adv. Learn.* II: *Works* iii.352)

And later in the same work he tells us:

I like better that entry of truth which cometh peaceably with chalk to mark up those minds which are capable to lodge and harbour it, than that which cometh with pugnacity and contention. (*Works* iii.363)

In the context of English thought in the early-modern era, the advocacy of experiment over Scholastic disputation, and the advocacy of a 'civil'

¹⁰ Two recent accounts of Bacon's reforms have drawn attention to this aspect of his programme: Julian Martin, *Francis Bacon, the State, and the Reform of Natural Philosophy* (Cambridge, 1992), and John E. Leary, Jr., *Francis Bacon and the Politics of Science* (Ames, Iowa, 1994).

¹¹ The phenomenon was not confined to England. For an overview of the situation in England and continental Europe, see Lorraine Daston, 'Baconian Facts, Academic Civility, and the Prehistory of Objectivity', in Alan Megill, ed., *Rethinking Objectivity* (Durham, N.C., 1994), 37–63.

approach in which some form of compromise is sought in scientific and philosophical matters, are indissolubly linked.¹² One crucial thing at stake in both is a rejection of Scholastic disputation: It is both the wrong way for natural philosophy to be pursued and the wrong way for natural philosophers to behave. The key idea is that civility and good sense dictate that one should pursue a *via media*, some form of middle position which both parties to a dispute could accept.¹³

Boyle is perhaps the best example of this linking of the appropriate form of natural-philosophical practice with the behaviour appropriate to the natural philosopher. There is a constant attempt in Boyle to find a *via media* in metaphysical disputes. The corpuscular hypothesis, he tells us, is something that transcends metaphysical disputes between the Cartesian and Epicurean schools, whose hypotheses 'might by a person of a reconciling disposition be looked on as . . . one philosophy.'¹⁴ Eclecticism is presented here as an ingredient in gentlemanly behaviour, something to be contrasted with the adversarial mode of Scholastic disputation. Boyle is possibly developing a theme in Bacon, for Bacon himself explicitly defends the *via media*, telling us in *Temporis Partus Masculus* that Democritus 'destroyed two falsehoods by knocking their heads together and opened up a middle path to truth.'¹⁵ In the *De Sapientia Veterum*, he uses the images of steering between Scylla and Charybdis, and of the flight of Icarus: 'Moderation or the Middle Way is in Morals much commended, in Intellectuals less spoken of, though not less useful and good.'¹⁶ And, as we shall see, Bacon's theory of 'method', as well as being designed to increase human collective power to discover natural laws and manipulate natural processes, was also intended, as a means to achieving this power, to provide a strict regimen which continually

12 See the discussion of the 'gentlemanly' mode of argument in Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth Century England* (Chicago, 1994), and Steven Shapin and Simon Schaffer, *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, 1985).

13 The notion of a *via media*, which Aristotle had employed in an ethical context, also played an important role in political theory – e.g., in chap. 23 of Niccolò Machiavelli's *The Prince* (trans. George Bull [London, 1970]) – and it is quite likely that both these areas served as models in some respects, although I have been unable to trace out exact correspondences.

14 Preface to *Some Specimens of An Attempt to make Chymical Experiments useful to illustrate the notions of the Corpuscular Philosophy*, in *The Works of the Honourable Robert Boyle*, ed. T. Birch, 2d ed., 6 vols. (London, 1772), i.355–8; quotation from p. 356.

15 *Works* iii.537; Benjamin Farrington, *The Philosophy of Francis Bacon: An Essay on Its Development from 1603 to 1609 with New Translations of Fundamental Texts* (Chicago, 1964), 71.

16 *Works* vi.754.

curbed the spontaneous tendencies of the mind. This can be done because of the manipulability of the human mind:

But certain it is . . . that as the most excellent of metals, gold, is of all other the most pliant and most enduring to be wrought; so of all living and breathing substances, the perfectest (Man) is the most susceptible of help, improvement, impression, and alteration. And not only in his body, but in his mind and spirit. And there again not only in his appetite and affection, but in his power of wit and reason. (*Works* vii.99)

Later, comparing the lame man who, because he takes the right road, outstrips the swift runner who has taken a wrong road, and whose very swiftness leads him further and further from his goal, Bacon explains that his way of discovery in science 'leaves but little to the acuteness and strength of wits, but places all wits and understanding nearly on a level',¹⁷ repeating the point later in *Novum Organum*:

For my way of discovering sciences goes far to level men's wits, and leaves but little to individual excellence; because it performs everything by the surest rules and demonstrations. (*Nov. Org.* I cxxii: *Works* i.217/iii.109)

Bacon's is a theory about how to shape scientists (as they will subsequently come to be known), so that, contrary to their natural inclinations, they manifest the requisite good sense and behaviour in their observation and experiment. Avoiding extremes is important here – to avoid the 'Idols of the Cave', for example, we must steer a middle course between 'extreme admirations for antiquity' and 'extreme love and appetite for novelty'¹⁸ – and it is indicative of the fact that Bacon's proposals are as much about reforming behaviour as about following productive procedures.

It may be helpful to think of this reform of behaviour in two ways. In the first place, it is clearly an extension of the emphasis on civility that we find from the late fifteenth century onwards, which is exemplified in the numerous manuals which appeared in the sixteenth century, describing in detail how one should behave – that is, regulate one's behaviour – in a variety of circumstances. In an extremely popular and influential series of manuals that Erasmus published between 1500 and 1530, for example, there are set out rules for how to behave in church, in bed, while at play, while eating, and so on; the manuals are exhaustive, covering everything from dress, deportment, and gestures, to facial expres-

17 *Nov. Org.* I lxi: *Works* i.172/iii.62–3. Compare the claim, in the Preface to the *Instauratio Magna*: *Works* i.129/iv.18, that no degree of 'excellence of wit' can enable us to overcome the obstacles to uncovering the secrets of nature.

18 *Nov. Org.* I lvi: *Works* i.170/iii.59–60.

sions and demeanours.¹⁹ Erasmus's *De Civilitate Morum Puerilium* appeared in English as *A Lytell Booke of Good Maners for Chyldren* in 1532 and spawned a large number of books on these topics: Among them (to confine our attention to the more popular early-seventeenth-century works) were James Cleland's *Hero-Paideia; or, The Instruction of a Young Nobleman* (Oxford, 1607), William Fiston's *The Schoole of Good Manners* (London, 1609), Richard Weste's *The Booke of Demeanour* (London, 1619), Henry Peacham's *The Compleat Gentleman* (London, 1622), and Robert Brathwayt's *The English Gentleman* (London, 1630).²⁰ Bacon's *Essayes* – in their final edition entitled *The Essayes or Counsels, Civill and Morall* – can be seen as making some contribution to this genre, as they deal with various passions and how to control them, and offer advice on various social questions: parenthood, marriage, friendship, custom, education, and so on.²¹

It may also be helpful, however, to compare Bacon's plan to direct scientific activity by inculcating new habits in scientists with the much later reform of medical practice, inaugurated by Joseph Lister in the late 1860s, whereby surgeons and nursing staff were subjected to a new and severe regimen conducive to antiseptic conditions, a regimen which required a complete change in the deportment of surgical and medical staff. Indeed, it is difficult to imagine that the kind of highly regulated regime of cleanliness and alertness to infection that Lister introduced could have been possible unless there was already an ethos of self-examination and responsibility for the self which effectively begins in earnest with the kind of intense moral self-examination that we find in the sixteenth century.²² Subjection to such regimes, which involve a sig-

19 There is a representative selection of these writings in translation in section 2 of *The Erasmus Reader*, ed. Erika Rummel (Toronto, 1990). On the role of civility and etiquette, see Norbert Elias, *State Formation and Civilization* (Oxford, 1982) and his *The Court Society* (Oxford, 1983); and more specifically on civility in England, Sir Ernest Barker, *Traditions of Civility* (Cambridge, 1948).

20 On this genre in England, see Anna Bryson, 'The Rhetoric of Status: Gesture, Demeanour and the Image of the Gentleman in Sixteenth- and Seventeenth-Century England', in Lucy Ghent and Nigel Llewellyn, eds., *Renaissance Bodies: The Human Figure in English Culture, c. 1540–1660* (London, 1990), 136–53. The genre is transformed into a concern with politeness in the eighteenth century: See Lawrence Klein, *Shaftesbury and the Culture of Politeness* (Cambridge, 1994).

21 *Works* vi.371–517.

22 As Jean Delumeau has pointed out, the problem for both Reformation and Counter-Reformation 'was how to persuade hundreds of millions of people to embrace a severe moral and spiritual discipline of the sort which had never actually been demanded of their forebears, and how to make them accept that even the most secret aspects of their daily lives should thenceforth be saturated by a constant pre-occupation with things eternal' ('Prescription and Reality', in Edmund Leites, ed.,

nificant degree of self-regulation, requires that one already have certain skills and capacities, that one already have a certain 'mentality' which places a value on these, and Bacon clearly sees part of his task as inculcating the requisite skills and capacities by instilling the requisite mentality.

Practical knowledge

At the heart of this reform is the production of useful knowledge. The practical nature of knowledge is a particularly pressing issue for Bacon – as we shall see, he denies the title 'truth' to anything unless it is 'productive of new works' – so it is important that we understand what is at stake in this question. The concern with practical knowledge and the practical benefits of knowledge was especially marked in sixteenth-century England. Scholastic disputation was rejected in part because it was considered to be of no benefit to anyone, and there was a tendency among the English humanists of the sixteenth century to consider the practical sciences superior to theoretical knowledge.²³ The Tudor humanist and alchemist Thomas Starkey wrote in the 1530s that

the perfection of man standeth not in mere knowledge and learning without application of it to any use or profit of others, but the perfection of man's mind resteth in the use and exercise of all virtues and honesty, and chiefly in . . . the communing of high wisdom to the use of others.²⁴

In writers outside the context of humanism, we can find a rejection of the classical tradition and an emphasis on many of the elements that Bacon will take up: above all, observation and experiment. One area in which this was particularly pronounced is geography, where the limits of classical writings had become very obvious in the voyages of discov-

Note 22 (*cont.*)

Conscience and Casuistry in Early Modern Europe [Cambridge, 1988], 134–58, at 144). Delumeau has looked at this question in detail in his tetralogy: *La Peur en Occident (XIV^e–XVIII^e siècles): Une cité assiégée* (Paris, 1978); *Le Pêché et la peur: La Culpabilisation en Occident, XIII^e–XVIII^e siècles* (Paris, 1983); *Rassurer et protéger: Le Sentiment de sécurité dans l'Occident d'autrefois* (Paris, 1989); and *Une Histoire du Paradis: Le Jardin des délices* (Paris, 1992). See also Gerhard Oestreich, *Neostoicism and the Early Modern State* (Cambridge, 1982), especially chap. 11, 'The Structure of the Absolute State', and R. Po-Chia Hsia, *Social Discipline in the Reformation* (London, 1989).

23 See F. Caspari, *Humanism and the Social Order in Tudor England* (Chicago, 1954), on the importance of the practical sciences for sixteenth-century English humanists, and Paolo Rossi, *Francis Bacon: From Magic to Science* (Chicago, 1968), on the importance of this for Bacon.

24 Thomas Starkey, *A Dialogue between Reginald Pole and Thomas Lipset*, ed. K. M. Burton (London, 1948), 26. Cited in Caspari, *Humanism and the Social Order*, 118.

ery of the fifteenth and sixteenth centuries. Of the three discoveries that the Elizabethans lauded – gunpowder, printing, and the magnetic compass needle – it was the last, as Jones has pointed out, that appeared the most significant, 'not only because it was largely responsible for the discoveries that amazed and thrilled the age, but also because its mystery defied explanation and invited attention and study.'²⁵ And it is in the writers on magnetism that we find the strongly held view that the classical authors have little to offer and that one must start afresh. Gilbert is the best-known example of this attitude, but we can also find it in far less learned writers, such as the seaman turned instrument maker Robert Norman, who, in his *The newe Attractiue* (1581), attacks those who seek knowledge from Latin and Greek texts – they are pedants who promise much and perform little – and offers an empirically based, as opposed to a textually based, procedure:

I meane not to vse barely tedious coniectures or imaginations, but briefly as I maie to passe it ouer, foundyng my arguements only vpon experience, reason, and demonstration, whiche are the groundes of Artes.²⁶

This attitude is taken up by other English writers of the period – by Thomas Blundeville, most noted for his writings on horsemanship and horsebreeding, in his *Exercises* on cosmography, astronomy, geography, and the art of navigation (London, 1594), and by William Barlow, in his *The Navigator's Supply* (London, 1597).²⁷ Gilbert, likewise, in 1600, in the Preface to his *De Magnete*, makes it clear that a new start is needed:

It is permitted us to philosophize freely and with the same liberty which the Egyptians, Greeks, and Latins formerly used in publishing their dogmas: whereof very many errors have been handed down in turn to later authors: and in which smatterers still persist, and wander as though in perpetual darkness. To those early forefathers of philosophy, Aristotle, Theophrastus, Ptolemy, Hippocrates, and Galen, let due honour be ever paid: for by them wisdom hath been diffused to posterity; but our age hath detected and brought to light very many facts which they, were they now alive, would gladly have accepted. Wherefore we also have not hesitated to expound in demonstrable hypotheses those things which we have discovered by long experience.²⁸

25 Richard Foster Jones, *Ancients and Moderns: A Study of the Rise of the Scientific Movement in Seventeenth-Century England* (New York, 1982), 13.

26 Quoted in *ibid.*, 14.

27 See the discussion in J. A. Bennett, 'The Challenge of Practical Mathematics', in Stephen Pumfrey, Paolo L. Rossi, and Maurice Slawinski, eds., *Science, Culture and Popular Belief in Renaissance Europe* (Manchester, 1991), 176–90, at 186–9.

28 William Gilbert, *On the Magnet*, trans. Silvanus P. Thompson (New York, 1958), *iii recto. This is admittedly an extreme statement by Gilbert of his position, and his attitude to antiquity is elsewhere a little more ambivalent.

The often eclectic, unsystematic nature of practical knowledge takes on a new significance when this practical knowledge is explicitly valued more highly than theoretical knowledge. The chief desideratum is practical application, rather than consistency or compatibility with first principles, and in these circumstances a lack of consistency is not likely to be treated as a major failing, if it is noticed at all. This is important in the case of Bacon, for he tended to treat the value of philosophy in terms of its ability to contribute to the general welfare. As he puts it in *Novum Organum*, 'the true and lawful goal of the sciences is none other than this: that human life be endowed with new discoveries and powers.'²⁹ This idea, widely accepted in the seventeenth and eighteenth centuries as providing the rationale for natural philosophy, was set out eloquently by Joseph Priestley in 1768:

[A]ll knowledge will be subdivided and extended; and knowledge, as Lord Bacon observes, being power, the human powers will, in fact, be increased; nature, including both its materials, and its laws, will be more at our command; men will make their situation in this world abundantly more easy and comfortable; they will probably prolong their existence in it, and will grow daily more happy, each in himself, and more able (and, I believe, more disposed) to communicate happiness to others.³⁰

What these kinds of concerns bring to light is something that goes beyond the relation between practical and theoretical knowledge: It raises the question of the aims of knowledge per se. There is a temptation here to think in terms of a divide between 'high science', which aims at truth, and 'low science', which aims at usefulness. But the matter is not so straightforward. Discussions of the standing of science in the twentieth century, in particular, especially as far as philosophers are concerned, have tended to subordinate usefulness to truth: It is ultimately in virtue of being true that theories are useful, so what one must seek is truth. It is this kind of conception that lies behind the idea that the core of Bacon's approach lies in his 'method', or in epistemological questions about the adequacy of induction. Now of course there were questions of truth raised in seventeenth-century natural-philosophical thought, and these did occasionally turn on the nature of the truth that natural philosophy was supposed to capture – whether the aim was simply to

29 *Nov. Org.* I, Aph. 81: *Works* i.188/iii.79. Compare *De Interp. Nat.*, where we are told that the dignity of knowledge is maintained by works of usefulness and power: *Works* iii.519.

30 Joseph Priestley, *Essay on Government* (London, 1768), 6. The Baconian theme of the usefulness of knowledge comes into its own in the eighteenth century: See Larry Stewart, *The Rise of Public Science: Rhetoric, Technology, and Natural Philosophy in Newtonian Britain, 1660–1750* (Cambridge, 1992).

find something compatible with the evidence, for example, or whether it was to discover how things really are. The question whether a Copernican model of the solar system had a physical interpretation which offered a uniquely true account of the motion of the Sun and the planets is perhaps the best-known example of such a dispute; but in the seventeenth century, this was only one of a number of questions about the nature and aims of scientific understanding, and it was not the issue to which one looked for a rationale for scientific practice. To treat it as the predominant issue will inevitably bring confusion. Bacon's claim that knowledge is power, for example, is widely treated as a provocative claim about knowledge, as if it were on a par with claims that knowledge is a grasp of Forms or universals. But it should in fact be read as a claim about power, about something practical and useful, telling us that knowledge plays a hitherto unrecognised role in power. The model is not Plato but Machiavelli.

There is an instructive comparison to be made here between Bacon's approach and the traditional separation of the practical and the theoretical realms that we find, for example, in Thomas Stanley's *History of Philosophy* (1655–62) – the first history of philosophy in English, and widely read in seventeenth-century England – where the work is broken up along the lines of practical and theoretical philosophical concerns:

Now the life of Man being either *practick*, busied in civil affairs of peace and war, or *Contemplative*, retir'd from publick business to speculation and study of wisdom, Divine or Humane, it follows that this personal history will be twofold likewise.³¹

Compare this with Bacon's diametrically opposed view in a letter of advice to James I on the union of Scotland and England in 1603:³²

I do not find it strange . . . that when Heraclitus, he that was surnamed the obscure, had set forth a certain book which is not now extant, many men took it for a discourse of nature, and many others took it for a treatise of policy and matter of estate. For there is a great affinity and consent between the rules of nature, and the true rules of policy: the one being nothing else but an order in the government of the world, and the other an order in the government of an estate. And therefore the education and erudition of the kings of Persia was in a science which was termed by a name then of great reverence, but now degenerate and taken in ill part: for the Persian magic, which was the secret literature of their kings, was an observation of the contempla-

31 Thomas Stanley, *The History of Philosophy: containing the Lives, Opinions, Actions and Discourses of the Philosophers of every Sect*, 2nd ed., 3 vols. (London, 1687), vol. i (n.p.; ¶3 of the Preface).

32 'A Brief Discourse touching the Happy Union of the Kingdoms of England and Scotland', *Works* x.90.

tions of nature and an application thereof to a sense politic; taking the fundamental laws of nature, with the branches and passages of them, as an original and first model, whence to take and describe a copy and imitation for government. (*Works* x.90)

Bacon's aim is to shape political power around political understanding, and he will argue that this political understanding should ultimately take into account broader forms of knowledge, especially scientific knowledge. His point is not to redefine epistemology but to underpin the responsible use of power.

Among the many respects in which Bacon's advocacy of the practical nature of knowledge shapes his understanding of natural philosophy, there are three that are particularly worth noting: the classification of knowledge; the use of mathematics in natural philosophy; and the role of eclecticism.

The classification of knowledge

In Book 2 of the *Advancement of Learning*, a comprehensive attempt is made to classify the whole of learning,³³ and Bacon's classification is different from traditional ones. Classifications of knowledge had been reasonably common since Aristotle. Although Aristotelian writers such as Zabarella had maintained that any ordering of knowledge must be restricted to individual disciplines and could not be based upon principles unifying separate disciplines, there was no shortage of encyclopædic works in the sixteenth and seventeenth centuries attempting just that, and the idea that a comprehensive classification of knowledge might enable one to discover its gaps and make knowledge more readily transmissible gained popularity throughout the sixteenth and seventeenth centuries.³⁴

In the early-modern era these classifications tended to be motivated didactically, even though the principles of organisation underlying them

33 A diary entry reveals that Bacon considered the project of translating the *Advancement* as early as 1608 (*Works* xi.64). By the time he came to realise this project, in 1624, the work had been expanded. The original *Advancement of Learning* had appeared in two books: Book 1 is virtually identical in the two cases, but Book 2 of the *Advancement* is now divided up into eight books, considerably increased in size from the original. Nevertheless, even in the case of the doctrine of Idols, the difference lies mainly in the addition of detail rather than in the development of new material, and neither the division of subject matter nor the sequence in which questions are discussed deviates significantly from that of the *Advancement*. The notes to the Spedding and Ellis edition of the *Advancement* indicate where additions, expansions, and rearrangements of material have been made in *De Augmentis*.

34 See Leroy E. Loemker, *Struggle for Synthesis: The Seventeenth Century Background of Leibniz's Synthesis of Order and Freedom* (Cambridge, Mass., 1972), 32–6.

may have been relatively abstract.³⁵ The proposed reforms of Ramus, for example, brought with them new ways of classifying knowledge which were based on a new understanding of the nature and role of rhetoric and logic, but the classification was shaped largely by didactic concerns. This meant that things that were not part of the curriculum – and especially those that were not part of the seven liberal arts, which had dominated the curriculum during both the Middle Ages and the Renaissance – tended to be excluded. Aristotle had offered a general classification of knowledge that was based on what he considered to be fundamental distinctions in types of knowledge. He had divided knowledge into the theoretical, productive, and prudential arts/sciences, and subdivided the theoretical into those that deal with what is unchanging and independent ('first philosophy'), with what is unchanging but dependent (mathematics), and with what is changing but independent (natural philosophy), and this classification was still widespread in Bacon's time, Bacon himself adhering to some aspects of it. However, there were areas which Aristotle's and didactically motivated classifications either ignored or marginalised, and sixteenth-century writers tried to incorporate these into their classifications. Cardano's *De Subtilitate* (1550) and *De Rerum Varietate* (1557), for example, cover natural philosophy and various secrets of the trades and medicine. Jakob Wecker's *De Secretis* (1582) moves from the metaphysical and natural-philosophical implications of creation to how to counterfeit coins and gems and how to catch fish. Della Porta's *Magia Naturalis* (1558) deals with many categories usually excluded from classifications of knowledge either because they were considered too ephemeral (the art of beautifying women) or because they cover 'marvels' (optical tricks, invisible writing, etc.); but he also dealt with practical questions in metallurgy and optics which, if they had been covered in other classifications, were covered inadequately. Bacon is keen to include both theoretical and practical knowledge in his classification, and it is guided less by didactic considerations than by an attempt to map out all the kinds of knowledge of which the rational mind was capable, and to find out where the realm of learning is in good shape and where it is in need of cultivation.

At the beginning of Book 2 of the *Advancement of Learning*, Bacon makes it clear that the parts of his 'small globe of the intellectual world', whether civil or scientific, religious or mechanical, are inseparably connected. The 'partitions' between parts of knowledge, he tells us, should 'be accepted for lines and veins, than for sections and separations.' All parts of learning must be 'nourished and maintained from the common fountain,' or else the particular sciences will become 'barren, shallow

35 See the discussion in Lisa Jardine, *Francis Bacon: Discovery and the Art of Discourse* (Cambridge, 1974), chap. 1.

and erroneous.³⁶ Yet Bacon conceives the *philosophia prima* that provides the basic unifying principles underlying knowledge in a way very different from Aristotle and the majority of Scholastic metaphysicians. It is not metaphysics conceived as a science of being-qua-being, as it was for Aristotle. Above all, the particular sciences cannot be subsumed under metaphysics as if they were species of a general genus.³⁷ To think of things in this fashion would effectively be to deny the autonomy of natural philosophy, but this autonomy is something that Bacon has to defend; indeed, it is a *sine qua non* of his project, as we shall see. Natural philosophy will be transformed by Bacon into the paradigm of a practical and useful enterprise, and he certainly does not consider metaphysics in this vein. So one very important thing his classification does (a point to which we shall return in Chapter 3) is to free natural philosophy from the constraints that had traditionally been placed upon it, constraints which prevented it from being pursued in the practical vein that Bacon envisages.

Mathematics and practical learning

The usefulness of mathematics was a disputed question in sixteenth- and early-seventeenth-century England. There was no shortage of able mathematicians in the British Isles,³⁸ and there were attempts to intro-

36 *Adv. Learn.* II: Works iii, 366–7.

37 See the discussion in Robert McRae, *The Problem of the Unity of the Sciences: Bacon to Kant* (Toronto, 1961), 24–31.

38 The greatest of them all, Thomas Harriot, was a profoundly original mathematician, pioneering the development of algebra, and in the realm of practical mathematics he made no less significant advances in geometrical optics and the mathematical theory of navigation. On Harriot's contribution to algebra, see Johannes A. Lohne, 'Dokumente zur Revalidierung von Thomas Harriot als Algebraiker', *Archive for History of Exact Sciences* 3 (1966–7), 185–205, and his 'Thomas Harriot als Mathematiker', *Centaurus* 11 (1965), 19–45. On his work in navigational theory, see Jon V. Pepper, 'Harriot's Calculation of the Meridional Parts as Logarithmic Tangents', *Archive for History of Exact Sciences* 4 (1968), 359–413, and his 'Harriot's Earlier Work on Mathematical Navigation: Theory and Practice', in John W. Shirley, ed., *Thomas Harriot: Renaissance Scientist* (Oxford, 1974), 54–90. Among the other mathematicians, the most outstanding is John Napier, a Scotsman, who seems to have been investigating imaginary roots of equations around 1570, sixty years before Descartes (his investigations appeared as *De Arte Logistica* (ed. Mark Napier [Edinburgh, 1839])), and he issued the first set of logarithms in 1614 (*Mirifici Logarithmorum Canonis Descriptio, ejusque usus* . . . [Edinburgh]). Also worthy of mention are Henry Briggs, the first Savilian professor of geometry at Oxford, who issued a vastly improved set of logarithmic tables in 1617 (*Logarithmorum Chilias Prima* [London]), and William Oughtred, who produced a concise survey of arithmetic and algebra in his *Clavis Mathematicæ* of 1631 (London, 1648).

duce mathematical studies, but there was also extensive resistance to the teaching and improvement of mathematics. Many of the disputes between these camps hinged on the question of the practical usefulness of mathematics.

The reformers were particularly concerned to press its practical uses. Around 1570, two attempts were made to reform the English system of education, with implications for natural philosophy. The first was a project for a University of London, which took up some of the reforms of Sir Nicholas Bacon (Francis's father). The project was set out in Sir Humphrey Gilbert's *Queene Elizabethes Academy*,³⁹ which appeared some time in the mid to late 1560s. Gilbert was one of England's foremost advocates of colonisation, and he was concerned that the education system of the time left students ill-fitted for this task. He proposed a more practically orientated programme involving, among other things, intensive language learning as well as practical mathematical skills in artillery and fortification.⁴⁰ The proposed reforms got nowhere, however.

More radical was John Dee's *Mathematicall Præface* to the first English translation of Euclid's *Elements of Geometry*,⁴¹ in which he proposed a comprehensive overhaul of the natural philosophy of the day. Although what Dee is concerned with is the promotion of arcane knowledge,⁴² his program for reform is clearly motivated by what he perceives

39 Sir Humphrey Gilbert, *Queene Elizabethes Academy*, ed. F. J. Furnivall for the Early English Text Society (London, 1869).

40 Gilbert's work is discussed in Rossi, *Francis Bacon: From Magic to Science*, 6–7, and in Farrington, *Philosophy of Francis Bacon*, 12–13.

41 The most convenient edition is John Dee, *The Mathematicall Præface to the Elements of Geometrie of Euclid of Megara (1570)*, with an introduction by Allen G. Debus (New York, 1975). The translation was the work of Henry Billingsley – a merchant and later mayor of London – although Dee made a number of annotations to the translation, and corrected it in some places (*The Elements of the Geometrie* . . . [London, 1570]). Billingsley, like Dee, had been educated at St. John's College, Cambridge, where there was some interest in mathematics in the 1540s and 1550s. His translation was made not from the Greek, but from the Latin version attributed to Campanus. See W. R. Shenton, 'The First English Euclid', *American Mathematical Monthly* 25 (1928), 505–11.

42 The better-known writings, such as the *Propædeumata Aphoristica* (London, 1558) and the *Monas Hieroglyphica* (Antwerp, 1564), were concerned with arcane knowledge, and its arcane nature plays a significant role in its cognitive standing: See Frances Yates, *The Occult Philosophy in the Elizabethan Age* (London, 1979), chap. 8. Generally on Dee, see Nicholas Clulee, *John Dee's Natural Philosophy* (London, 1988); Peter J. French, *John Dee: The World of an Elizabethan Magus* (London, 1972); and William H. Sherman, *John Dee: The Politics of Reading and Writing in the English Renaissance* (Amherst, 1995). The 'Præface' is relatively silent about the question of the arcane knowledge, but, read in the context of his other writings, there can be little doubt that the Neoplatonism he advocates there is part of a package in which the arcane nature of true knowledge is central.

to be its practical benefits. His discussion of the two disciplines of mathematics, arithmetic and geometry, immediately reveals the scale and significance of his project. Arithmetic – which Dee treats with some sophistication, taking us through various techniques in Cossist algebra – is, he tells us, important not only for the merchant, but also for the physician who needs to know the proportions in which medicines are to be mixed, for the military commander who needs to arrange his soldiers in battle in the most effective way and to calculate how much food will be needed for them, and for the judge and legislator, who must apportion sums according to the law,⁴³ and he describes the practical applications of mathematics in areas such as astronomy, music, statics, cosmography, perspective, and hydrography. Having set out the principal uses of mathematics, Dee ends his account by raising the problem of whether an English translation of Euclid would offer a threat to the universities. Telling us how Italian, German, Spanish, and French translations of Euclid have not harmed continental universities, he proceeds to the benefits of a mathematical education for university students:

And surely, the Common and Vulgar Scholer (much more, the Gramarian) before his comming to the *Vniuersitie*, shall (or may) be, now (according to *Plato* his Counsell) sufficiently instructed in *Arithmetike* and *Geometrie*, for the better and easier learning of all manner of *Philosophie*, *Academicall*, or *Peripateticall*. And by that meanes, goe more cherefully, more skilfully, and speedily forward, in his Studies, there to be learned. And, so, in lesse time, profite more, then (otherwise) he should, or could do. Also many good and pregnant English wittes, of young Gentlemen, and of other, who neuer intend to meddle with the profound search and Studie of Philosophie (in the *Vniuersities* to be learned) may neuerthelesse, now, with more ease and libertie, haue good occasion, vertuously to occupie the sharpnesse of their wittes: where, els (perchance) otherwise, they would in fond exercises, spend (or rather leese) their time: neither seruing God: nor furduring the Weale, common or priuate.⁴⁴

And, finally, the practical consequences for the ‘unlatined’ are spelt out:

Besides this, how many a Common Artificer, is there, in these Realmes of England and Ireland, that dealeth with Numbers, Rule, and Compasse: Who, with their owne Skill and experience, already had, will be hable (by these good helps and informations) to finde out, and deuise, new workes, straunge Engines, and Instrumentes: for sundry purposes in the Common Wealth? or for priuate pleasure? and for the better maintayning of their owne estate?⁴⁵

43 Dee, *Mathematicall Præface*, sig. *iiii^v–ai^v.

44 Ibid., sig. Aiii^r.

45 Ibid.

Dee's *Præface* was ignored by his contemporaries and successors alike, however. Whereas his defence of arcane learning, *Monas Hieroglyphica*, was reprinted four times in the hundred years after its first publication, and was the work on which Dee's reputation largely hung, the *Præface* was not reprinted until 1651, and was not even mentioned by natural philosophers such as Bacon and Boyle who, like Dee, were bent on reform.⁴⁶

Just as claims for the reform of mathematics were couched largely in terms of its practical usefulness, its opponents either attacked its practical usefulness or minimised what use it had. In Roger Ascham's *The Scholemaster* (1570), an extremely influential and very widely used practical guide to the day-to-day running of schools, there is explicit hostility, covering mathematics and logic, with stress placed on how 'mathematical

46 The reasons for the complete failure even to acknowledge Dee's programme are difficult to fathom. It is true that Dee's reputation suffered tremendously after the beginning of his association with the alchemist Edward Kelley in 1582, losing his royal patronage in 1583 and having his house at Mortlake, with his magnificent library and three alchemical laboratories, burned by a mob in the same year: See Deborah E. Harkness, *John Dee's Conversations with Angels: Cabala, Alchemy, and the End of Nature* (Cambridge, 2000). But during the 1570s he had had significant support at court, the queen and the privy councillors sponsoring his plan for calendar reform, and his work in areas such as navigation, and his trigonometric theorems for determining stellar parallax – see John Dee, *Parallacticæ Commentationis Praxeosque Nucleus Quidam* (London, 1573) – were well received. Moreover, his programme for reform in the 'Præface' had largely ignored the more contentious numerological aspects of his conception of mathematics, offering something resolutely practical, in an age when the practical value of knowledge was highly valued, as we have seen. The real problem, I believe, was that Dee failed to achieve a linking of practical mathematical skills with a theoretical interest in natural philosophy generally, despite his own efforts and those of his pupil, Thomas Digges: See Thomas Digges, *Alæ seu Scalæ Mathematicæ* (London, 1573), and the discussion in Francis R. Johnson, *Astronomical Thought in Renaissance England: A Study of English Scientific Writings from 1500 to 1645* (Baltimore, 1937), chap. 6. The two continued to be seen very much as different domains. Part of the problem here might have been that, although Dee's project of raising mathematics to the central natural-philosophical discipline had explicitly relied on an advocacy of Platonic and especially Neoplatonist ideas which were directly opposed to the teachings of Aristotle, he had not taken on the Aristotelian doctrine of the role of mathematics. This doctrine, set out in Book E of the *Metaphysics* and elsewhere, whereby mathematics deals only with abstractions and not with real physical things, was the basis for the understanding of mathematics in the universities, and Dee's programme was simply at odds with the common theoretical understanding of mathematics. Until Aristotle's authority in natural philosophy was undermined, Dee's attempt to explore the importance of mathematics in a practical context had no rationale, outside of his Neoplatonically inspired numerology.

heads' are 'unapt to serve the world.'⁴⁷ This advice sat well with not only the sorry state of general mathematical education but the mathematical practice in sixteenth-century England.⁴⁸ Government accounts

47 Roger Ascham, *English Works*, ed. William A. Wright (Cambridge, 1970), 282–8.

48 The backwardness of England in this respect is remarked upon in Ramus, *Proœmium Mathematicum* (Paris, 1567), 55–9. The situation in the rest of Europe with respect to formal education in mathematics was more complicated. German and Italian mathematics were in a relatively healthy state, with some very important texts on arithmetic appearing in the course of the sixteenth century, such as Girolamo Cardano, *Practica Arithmetica Generalis* (Mediolani, 1539); Gemma Frisius, *Arithmeticae Practicae Methodus Facilis* (Antwerp, 1540); Michael Stifel, *Arithmetica Integra* (Nuremberg, 1544); and Niccolò Tartaglia, *La Prima Parte del general trattato di Numeri e Misuri* (Venice, 1556). Yet the Jesuit mathematician and astronomer Christopher Clavius deplored the prejudice against mathematics and the low quality of mathematics instructors, and had recommended the teaching of mathematical subjects in Jesuit colleges in his pamphlet *Modus quo Disciplinæ Mathematicæ in Scholis Societatis Possent Promoveri* (Rome, 1586): See James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago, 1994), chap. 2, and Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago, 1995), chap. 2, on Clavius's reforms. As a result of his recommendations, and in spite of their denunciation to the Inquisition by Dominicans (see Rivka Feldhay, *Galileo and the Church* [Cambridge, 1995] on the Jesuit–Dominican disputes on this), some instruction in mathematics was given in Jesuit colleges, but only to that minority of students who stayed on at the college after the basic five years of study of classical (principally Latin) literature. In Descartes's college of La Flèche, for example, mathematics was taught in the second of the three senior years, but only as a subsidiary subject, and it is likely that Descartes got his teeth into mathematical problems only in the classes on military architecture and fortification in the army of Maurice of Nassau, in which he served in 1619, and above all in his collaboration with Isaac Beeckman, who had a background in engineering and practical mechanics, at the end of that year. I stress the practical background to Descartes's interest in mathematics because, generally speaking, mathematics – at least of any degree of sophistication – was not taught in universities at this time. Significant exceptions are the Collegio Romano, where Clavius held classes in mathematics from 1597 to 1610, and the Netherlands, where some mathematics and mechanics were taught in the universities at the end of the sixteenth century. On the former, see Lattis, *Between Copernicus and Galileo*, chap. 1; on the latter, see Klaas van Berkel, 'A Note on Rudolphus Snellius and the Early History of Mathematics in Leiden', in C. Hay, ed., *Mathematics from Manuscript to Print, 1300–1600* (Oxford, 1988), 156–61. It was in practical areas such as fortification, ballistics, architecture, calendar reform, hydrostatics, and shipbuilding that the requisite skills were to be picked up: As A. Rupert Hall has pointed out, 'the profession of the architect-engineer embraced the most sophisticated technology existing in the fourteenth, fifteenth, and sixteenth centuries; it was the one technical profession making large demands on organising and planning ability, drawing-office skills, taste, craft knowledge, and mathematical learning.' 'Science, Technology, and

were still kept in Roman numerals in Tudor England,⁴⁹ for example, and the basic English mathematics text from the middle of the sixteenth to the middle of the seventeenth century, Robert Recorde's *Arithmetick; or, The Grounde of Artes* (1540), was extremely elementary, having to begin by defending the use of Arabic numerals.⁵⁰ In the most influential education textbook of all in Tudor England, Sir Thomas Elyot's *The Boke Named The Governour* (1531),⁵¹ there is no explicit hostility to mathematics: It was just completely absent from the curriculum.⁵²

Bacon took a great interest in practical disciplines, but his attitude to mathematics was at one with Elizabethan educationalists.⁵³ He placed some educational store by mathematics, but he conceived the usefulness of pure mathematics exclusively in terms of helping the concentration, and he has little to say on practical or 'mixed' mathematics. In the *Advancement of Learning*, in pointing out the uses of 'pedantical knowledge' for the young, he remarks that 'if a child be bird-witted, that is, hath not the faculty for attention, the Mathematics giveth a remedy thereunto; for in them, if the wit be caught away but one moment, one is new to begin.'⁵⁴ Setting out the province of mathematics in more detail earlier in the same book, the picture offered is straight out of Aristotle:

The Mathematics is either Pure or Applied. To the Pure Mathematics are those sciences belonging which handle Quantity Determinate, merely severed from any axioms of natural philosophy; and these two are, Geometry

Warfare, 1400–1700', in M. D. Wright and L. J. Paszek, eds., *Science, Technology and Welfare* (Washington, 1969), 3–24, at 15, reprinted (with original pagination) as chap. 9 of his *Science and Society* (Aldershot, 1994).

49 Some parish accounts in England still used Roman numerals into the seventeenth century: See W. P. D. Wrightman, *Science and the Renaissance*, 2 vols. (Edinburgh, 1962), i.90.

50 Robert Recorde, *Arithmetick; or, The Ground of Arts . . . augmented by John Dee, enlarged by John Mellis* (London, 1654), 10–26. See French, *John Dee*, 163–5.

51 Bacon will discuss Elyot in his *Of Tribute*. See James Spedding, ed., *Bacon: A Conference of Pleasure* (London, 1870). The text given in *Works* vii.119–43 is corrupt.

52 It is true that there were occasional attempts to integrate mathematics into the curriculum. In his *Positions, wherein those primitive circumstances be examined, which are necessarie for the training up of children, either for skill in their booke, or health in their bodie* (1581), Richard Mulcaster, the first headmaster of Merchant Taylor's School, calls for more time to be spent on the natural sciences (1888 ed. [London], 239–40); but this was an isolated call, and in any case it was issued in the context of a defence of the paramount importance of classical learning.

53 But possibly not, it should be noted, with that of his father Nicholas, to whom Thomas Digges, in the dedicatory letter to his edition of his father's *A Geometrical Practise, named Pantometria* (London, 1571), recalls Nicholas Bacon and Leonard Digges discussing geometry together.

54 *Adv. Learn.* II: *Works* iii.415.